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PRINCIPAL INVESTIGATOR: Steven E. Wolf, MD

CONTRACTING ORGANIZATION: The University of Texas Southwestern Medical Center at
Dallas, Dallas, TX 75390

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14. ABSTRACT Our initial Study/Product Aim(s) were as follows: 1) To determine under what conditions compliance with nutritional goals are not met in severely burned adults, 2) To find strategies to address identified gaps in feeding to incorporate into a checklist with easy clinical utility, and 3) To develop and test a system that incorporates the above strategies. The system will provide points in a checklist for provider attention <u>and</u> decision support guidelines for appropriate changes to meet cumulative and current nutritional goals. In the first year of this award, we have moved forward by collecting data from several hundred severely burned subjects treated in the ICU on nutritional provision from 3 of the 4 centers involved. We have also established the software package upon which the platform will be based. In the coming year, these data will be used to find the gaps in nutritional provision and develop a system to address these through decision support tools.					
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Table of Contents

Introduction	4-5
Keywords	5
Overall Project Summary	5-6
Key Research Accomplishments	6
Reportable Outcomes	6
Conclusion	7
Publications, Abstracts, and Presentations	8-26
Appendix	27-30

INTRODUCTION

This project was created with the overall goal of producing a decision support tool to assist providers with administering nutritional support to the severely burned, and in particular the severely burned combat casualty. The project was devised in response to a Broad Agency Announcement from the Department of Defence in 2012 soliciting proposals for development and testing of checklists with burn care in the Intensive Care Unit. We submitted this proposal to develop a checklist for the provision of nutritional care which would be supported by decision support technology akin to what we had done previously with burn resuscitation. We assembled investigators from 4 Texas burn centers to submit data on nutritional provision in the burn ICU that would be analysed for gaps, and control theory algorithms applied to provide solutions for these gaps. These findings are to be used to develop software technologies to implement recommendations and assist providers in providing nutritional care. We had the following overall hypothesis: **A computerised checklist for the Burn Intensive Care Unit that provides guidelines and information on current and cumulative nutritional provision and decision support for subsequent nutritional orders improves compliance with nutritional goals.** We proposed to test this hypothesis through addressing the following *Specific Aims*:

- To determine under what precise conditions compliance with nutritional goals are not met in severely burned adults.

We proposed to gather continuous ICU nutritional data from adult burned patients in four burn centers and assess feeding rates in relation to local nutritional goals with identification of periods of upward and downward variability. These will be correlated to clinical events to **objectively define incidence and timing of gaps in feeding** and thus identify targets for improvement.

- To find strategies to address identified gaps in feeding.

After the above analysis we still expect to find gaps during initiation of feeding, during and after expeditions from the ICU for clinical tests and procedures, and in response to periods of higher risk for complications such as high gastric residuals or hypotension. We may also find other unexpected gaps which will be included in further analyses. We then propose to model and report the biologic responses to changes in feeding during these times to find safe strategies to meet calculated feeding rates, and determine safe times to temporarily increase feeding above usual goal rate to close measured gaps.

With completion of these two aims, we will be able to construct a checklist of a clinical and physiologic model and then a computerised decision support system that will perform two functions: the first will be to provide a display of current feeding rate, daily cumulative total with and without indexing to daily goals, and hospital stay cumulative total with and without indexing to cumulative goals. This will serve as a traditional checklist for nutritional provision for the severely burned. Second, the system will provide hourly recommendations for feeding rate to meet provider entered nutritional goals based upon biologically confirmed models and predictions. This is described in our third aim:

- To develop and test a system that incorporates the above strategies. The system will provide points in a computerised checklist for intermittent provider attention and decision support guidelines for appropriate changes to meet cumulative and current nutritional goals.

These aims are encapsulated in the following *Statement of Work*:

Background: Activity in the burn intensive care unit (BICU) is complex, variable, and can be difficult to coordinate towards the overall goal to improve outcomes. Relatively new technologies are available to assist providers with monitoring critical care activities to be aware of physiologic and treatment changes as well as provide recommendations meet these changes to reach desired goals. One such area in the BICU is in the area of nutrition; providers are in universal agreement to the advisability of feeding to meet nutritional goals, but in spite of this, only 70-80% of goals are typically met. This is thought to be due to temporary interruptions to decrease the risk of complications or to meet other goals. Further, providers are often unaware of

accumulating deficits over the hospitalisation, and if recognised need safe and effective strategies to temporarily accelerate feeding to meet goals.

Objective: To develop and implement a checklist with a decision support system to inform BICU providers of nutritional provision in relation to goals and provide a safe strategy to meet desired nutritional provision.

Project Breakdown:

TASK ONE (MONTHS 1-18): After award of funding, we will seek IRB approval then proceed with data collection of hourly nutritional delivery and associated feedback variables until enrollment goals are reached at the 4 study centers. These data will then be audited for reliability and reproducibility. **This has been completed.**

TASK TWO (MONTHS 19-24): Once the data are codified, these will be used to develop a physiologic model of feeding and associated responses across time in severely burned patients. From this model, a checklist and decision support system will be constructed to give providers a real-time assessment of progress towards nutritional goals as well as recommendations for changes in feeding based on model predictions to reach and maintain goals. **IN PROGRESS**

SUBTASK 1: Complete clinical data analysis for assessment of modern nutrition

SUBTASK 2: Complete clinical data analysis for risks of nutrition in the burn centre

SUBTASK 3: Complete construction of decision support tool and validate with the current database

TASK THREE (MONTHS 25-36): Once constructed, the Burn Nutrition and Decision Support System (BNS) will be tested for reliability in a crossover design to assess feasibility, reliability, safety, and efficacy. The final product will then be available for patent and FDA testing. **TO BEGIN IN 6 MONTHS**

SUBTASK 1: Obtain IRB approval to gather data

SUBTASK 2: Assess pilot use of the decision support device for use of the recommendations, effects of the recommendations on the provision of nutritional therapy, and assessment of use by nursing and physician staff

KEYWORDS

Nutrition, severe burn, decision support

OVERALL PROJECT SUMMARY

TASK ONE: We received IRB approval for collection of data at University of Texas – Southwestern Medical Center, University of Texas Health Science Center – Houston, the University of Texas Medical Branch in Galveston, and at the United States Army Institute of Surgical Research. We have completed collection of 100 subjects at UT-Southwestern, 42 at the University of Texas Health Science Center – Houston, 100 at the USAISR, and 100 at the University of Texas Medical Branch in Galveston. The data collection is now complete for the first two aims. We have analysed all the data for reliability and reproducibility; less than 1% of entries were adjusted, therefore we feel that these data are accurate and a full audit is superfluous. The preliminary results are as follows:

Two-hundred forty-two subjects were included. Median age was 41 [25,56], TBSA burned 37% [24,55], full thickness burn area 20% [8,43], 31% had inhalation injury. Admission weights were 79 kg [66,94], and discharge weights 70 kg [63,81]. Average weight loss during the hospitalisation was 7 kg [-15,-2] and percentage loss from admission weight was 9% [-17,-3]. Tube feedings were started on the day of admission in 43%, and within one day of admission in 78%; < 12% were started more than 48 hours from admission. Duration of tube feedings was 18 days [10,30] for this population; ICU days with tube feedings given was 91% [64,100], and for the whole hospitalisation was 67% [44,91].

TASK TWO:

We are now analysing the data to answer the following questions: when did the feeding deficits occur? Were more deficits associated with greater weight loss? Longer hospitalisation? Mortality? We expect this analysis

to be complete in Q1 2015 and will be submitted for presentation and publication in a major journal. Portions of the work have already been presented locally (please see the attached PowerPoint presentation to be given in Houston at the Southern Region of the American Burn Association Meeting in November), and two abstracts have been submitted for this year's meeting of the American Burn Association. One manuscript from a single center has been prepared for publication (see attached), but has not yet been submitted.

We are also using the data to determine whether any risks were encountered in the process of tube feedings. What about infections? Aspiration? Residuals and subsequent problems? We expect that this will be a separate analysis and publication, and will inform the development of the clinical tool in terms of safety.

Our plan for the next six months is to complete data analysis by adding the ISR subjects and assessing the clinical data and outcomes for a description of 'Nutrition and Nutritional Outcomes in the Modern Burn Center'. These data are more than sufficient for this purpose. The data to date are de-identified in a single file which will be used for all further work; the original data will be kept separate on a single locked computer; it is not available remotely.

During the first year, we constructed software upon which the checklist and decision support system will be employed. We created a computer program to serve as a checklist, which assures the performance of efficacious preventative activities by providing reminders, highlights attention to signals of worsening conditions, and provides guidance for the best response. This program contains a computer model for achieving caloric goals with unpredictable amounts of time allotted to provide these goals. This is done by overshooting the caloric goal and tapering off if there are no interruptions or increasing further if there are interruptions resulting in a caloric deficit (over the past 24 hours) for which the overshoot model has not already managed.

This initial version of the software contained guidelines included defining elevated gastric residuals as >500 ml or repeating values >300 ml, starting a gastric motility agent when high residuals occur, placing a post-pyloric feeding tube if the gastric motility agent does not resolve the elevated residuals, minimizing interruptions, and running a trophic feeding if an ileus occurs. We will be analysing the current data to determine if these guidelines were effective in mitigating risk of tube feedings. These reasons along with a list of common reasons already in the program will be evaluated and will allow us to create additional strategies to correct identified gaps in feeding. Please see **Appendix 2** for full details of the system developed thus far.

TASK THREE: Awaiting final product prior to testing. We expect that the tool will be completed and test-worthy in 6 months. During development, we will begin obtaining IRB approval for the single center rollout of the tool.

KEY RESEARCH ACCOMPLISHMENTS

- Institutional Review Board approval at all sites
- Data collection performed and is completed. All data have been analysed for reliability, and found to be accurate. Initial analysis has been performed showing significant weight loss in this population. Two abstracts and one manuscript have been constructed
- Development of the initial checklist tool for nutritional delivery in the Burn ICU. We will start with the adjustments from the findings of the multicenter study to develop the tool which will be completed in Q2 2015. We expect clinical assessment of the tool beginning in Q3 2015.

REPORTABLE OUTCOMES

See attached presentation and manuscript.

CONCLUSIONS

We have successfully started the study with data collection complete for development of this multicenter model. We have also begun construction of the checklist and decision support tool which we expect to be completed in 6 months. The last year will be used for clinical product testing.

Publications, Abstracts, Presentations

Abstract

PowerPoint presentation

Prepared manuscript

Checklist and Decision Support in Nutritional Care for Burned Patients

Bernal E, Ross E, Wolf SE

Type of Research: ☐ Basic/Translational or ☒ Clinical

Introduction:

Higher nutritional needs are associated with severe burns, supporting the use of immediate initiation of continuous tube feedings upon admission. However, evidence suggests that only 70-80% of the recommended calories are given. The additive effect of subsequent interruptions and changes in goal rates contribute to the overall failure of reaching 100% of individual goals. Potential causes for delays in initiation include urgent or emergent procedures, while potential causes of interruptions thereafter include expeditions from the ICU or pauses peri-extubation. Dedicated and consistent efforts to compensate for these delays or interruptions are currently lacking. Given that deficits in caloric intake are associated with poor long-term outcomes in severely burned patients, we set out to identify the causes of failure to reach these calculated caloric goals in 100 burned patients admitted to the ICU. After the collection of these data, our aim is to construct a system checklist in which providers can adjust hourly tube feedings real-time to work toward achieving 100% of daily caloric goals.

Methods:

A retrospective chart review of 100 burned patients admitted to the BICU who were initiated on tube feedings was conducted. Data were collected only for the length of first ICU stay per patient. Total hourly volume of tube feedings was recorded for each patient, with the daily goal calculated as the product of hourly goals and total number of hours expected for administration. The difference between tube feedings delivered and the sum of residuals and tube feeds discarded was determined as the actual tube feedings administered. The percentage of expected tube feeding goal was calculated per patient and for the group as a whole.

Results:

The average length of ICU stay was 23.34 days (range 2-189 days) with patients achieving 77.04% ($p < 0.01$) of expected goal tube feedings during first ICU stay. Average percent total body surface area and full thickness burn were 34.47% and 21.73%, respectively. Delays in initiation of tube feedings were rare and when present associated with urgent or emergent procedures. Interruptions in continuous tube feedings were attributable to operative intervention in non-intubated patients, trips to MRI, presumed sepsis, high residuals, and pauses peri-extubation attempts. Decreases in daily goal rates were attributable to transition to nocturnal tube feedings and attempts to encourage per os intake. Additionally and where noted, there were certain patient-dictated pauses in continuous tube feedings, due to refusal or noncompliance.

Conclusions:

Severely burned patients have high nutritional needs. Although efforts are made to initiate continuous tube feedings as soon as possible, many burned patients fail to reach their caloric goals. Expeditions from the ICU, pauses for extubation, and high residuals constitute obstacles that interfere with achievement of daily caloric goals. These interruptions can often be anticipated and be compensated for when identified. Given that poor nutritional status is associated with poor long term outcomes, it stands to reason that improvement in nutritional support would promote better outcomes, including the potential for quicker recovery. The information gathered will serve as the foundation for the construction of a system checklist that will enable providers to make more timely adjustments to hourly tube feedings with the overall aim of achieving 100% of expected daily and overall caloric goals. It is the expectation that such a system checklist will help minimize caloric deficits and improve outcomes.

Slide 1

CHECKLIST AND DECISION SUPPORT IN NUTRITIONAL CARE FOR BURNED PATIENTS

UTSW Research Forum, 2014
Eileen Bernal, MD

Slide 2

Nutrition in Burn Patients

- Higher nutritional needs
- Underfeeding is common
- Initiated during or immediately after resuscitation
- Enteral, parenteral, or both
- Only 70-80% of nutritional recommendations are met

Slide 3

Data Acquisition

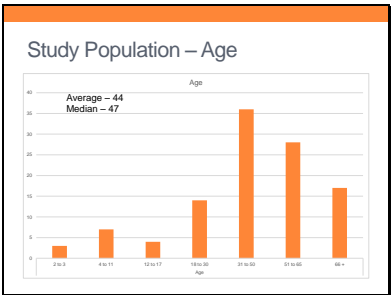
- Retrospective chart review of 100 patients
- Inclusion criteria
 - ≥ 1 day of tube feeds
 - Tube feeding initiated in Burn Intensive Care Unit (BICU)
 - Thermal or electrical injury
- Exclusion criteria
 - Readmission to the BICU after transfer to the sub-acute floor
 - Dermatological conditions
 - Isolated inhalational injuries without cutaneous burn

Slide 4

Data Acquisition

- Demographics
- Total body surface area burned (TBSA); size of full/partial thickness burn (FT/PT)
- Disposition
- Presence/absence of inhalational injury
- Admission/discharge weight
- Total ICU/hospital days
- Hourly tube feed volumes
- Surgical procedures undertaken during BICU admission
- Expeditions out of BICU
- Sepsis events

Slide 5



Slide 6



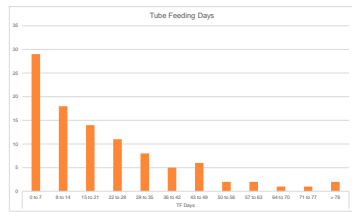
Slide 7

Initiation and Interruptions

- Tube feeding typically initiated on day of admission
- Most patients admitted to BICU had tube feeding started on Day 0 (70%)
 - Probability of tube feeding by Day 1 – 90%
- Tube feeding frequently initiated during resuscitation
- Tube feeding recorded for length of BICU admission only

Slide 8

Initiation and Interruptions

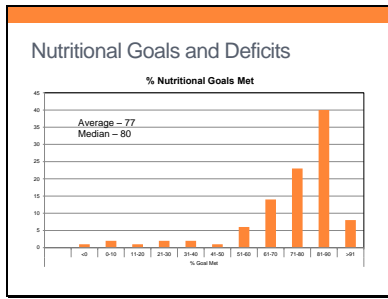


Slide 9

Initiation and Interruptions

- | | |
|----------------|------------------|
| • Delays | • Interruptions |
| • Escharotomy | • Operating room |
| • Bronchoscopy | • Radiology |
| | • Extubation |
| | • Sepsis |
| | • Noncompliance |

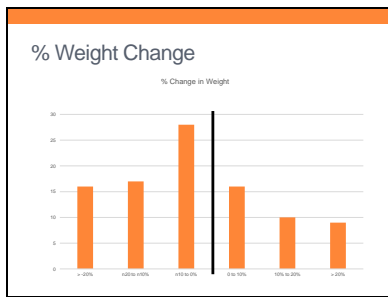
Slide 10



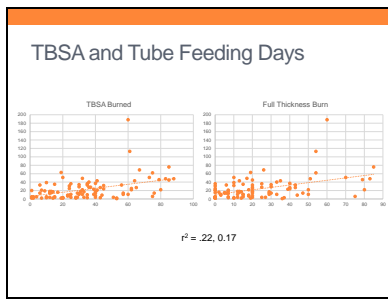
Slide 11



Slide 12



Slide 13



Slide 14

Future Work

- Real time interventions based on anticipated deficits
- Bedside checklist to compensate for interruptions
- Aim toward 100% achievement of nutritional goals
- Expect improvement in meeting nutritional goals will lead to improved outcomes

Difference between Recommended Calories and Calories Received in Adults with Massive Burns

Nicole C Benjamin BS^{1,2}, Jong O Lee MD^{1,2}, Jamie M Heffernan RN¹, Steve E Wolf MD FACS³, Oscar E Suman PhD^{1,2}, Ronald P Mlcak PhD,^{1,2} Clark R Andersen MS^{1,2}, David N Herndon MD FACS^{1,2}

¹University of Texas Medical Branch, Galveston, Texas 77555-0833; ²Shriners Hospitals for Children, Galveston, Texas 77550-0833;

³University of Texas Southwestern, Dallas, Texas 75390-9158.

Correspondence: David N. Herndon, M.D., 815 Market St., Galveston, TX 77550, Phone: (409) 770-6731, Fax: (409) 770-6919, Email:dherndon@utmb.edu.

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Conflicts of interest: None

Abstract

Objective: In an effort to attenuate the hypermetabolic response that results from a severe burn injury, aggressive and early enteral nutrition is prescribed. Despite the best intent to treat, a trend of weight loss in adult patients has been observed, thus, a review of the medical record was undertaken.

Methods: Analyses were performed on 45 surviving burned patients, who were at least 18 years of age, and admitted to a burn center from 2009-2014. Nutritional intake and weights were analyzed for the first 30 days after admission. Change in weight over time was analyzed using a mixed linear model. Caloric deficit over time was analyzed using a generalized additive mixed model.

Results: Patients were an average of 44 years of age, 83 kg, and predominantly males with large burns. There was an average loss of weight by 14% within the first 30 days of hospitalization. When calories received were compared to calories recommended based on REE x 1.2, REE x 1.4, Curreri formula, and Galveston Adolescent formula a mean deficit of 1200, 1700, 2500, and 3000 calories were delivered per day, respectively.

Conclusion: Our results show that even with the best intent to treat, a substantial weight loss is occurring in acute burn patients within the first 30 days of admission. Additionally, the amount of calories delivered was found to be less than what is suggested. Improved vigilance of monitoring calories delivered may help decrease possible weight loss.

Key Words: burn; nutrition; calories; weight loss; hypermetabolic.

INTRODUCTION

Burn injuries result in the highest metabolic rate of any critical injury.¹ The metabolic response that follows a severe burn injury is identified as a hypermetabolic state. Such a state is characterized by a hyperdynamic cardiovascular response, increased energy expenditure, accelerated glycogen and protein breakdown, lipolysis, loss of lean body mass and body weight, delayed wound healing, and immune depression.^{2,3} A net loss of protein post-burn results in muscle wasting and a decrease in lean body mass.^{4,5} A significant decrease in body mass and lean body mass may result in consequences detrimental to the patient.⁶

One method to attenuate the hypermetabolic response is aggressive and early enteral feeding.^{7,8} Several formulas have been created to address the postburn nutritional needs. Still, no one formula is perfect and some overestimate the number of calories needed by about 35-45%.^{9,10} It has been found that through measuring REE via indirect calorimetry using bedside carts, a more accurate and individualized representation of the actual caloric requirements can be determined.^{11,12} Still this method is not perfect.¹² It has been reported that feeding patients 1.2 times the measured REE leads to a 10% loss of lean body mass, but feeding patients 1.4 times the REE leads to an increase in fat deposition, but no increase in lean body mass.¹¹⁻¹³ Overfeeding has a myriad of detrimental effects, including, elevated respiratory quotients, increased fat synthesis, increased elimination of carbon dioxide, fat deposition in the liver, and hyperglycemia.¹⁴⁻¹⁶ It can be concluded that determining a patient's accurate caloric requirement is necessary for positive clinical outcomes.¹⁷

A trend of weight loss has been observed in adult patients at the Blocker Burn Unit of the University of Texas Medical Branch in Galveston, Texas (UTMB), despite the best intent to treat. We hypothesize that this weight loss currently observed is secondary to delivery of insufficient calories relative to recommendations from nutritional formulas and calculations. Thus, a thorough examination of the medical record process has been undertaken.

METHODS

Subjects

Analyses were done on 45 burned patients, who were at least 18 years of age. The patients were admitted to UTMB from May 2009 to May 2014 for treatment. This research project was performed under a UTMB, Institutional Review Board, approved protocol.

Clinical Care

All subjects were admitted to the burn unit and treated in a similar manner by a team of three burn surgeons. Standard treatment included early excision of third degree burn wounds, and continuous enteral feeding. Early excision involves patients undergoing total burn wound excision and grafting within 48 hours of admission for any third degree burns. Patients returned to the operating room as donor sites healed and allowed for reharvesting of the unburned skin (usually 7 to 10 days). Additional surgical procedures for excision and grafting were undertaken until all wounds were covered and healed.

Each subject received continuous enteral nutrition delivered via nasoduodenal tube using Dobhoff tube starting shortly after admission using Vivonex TEN (Sandoz Nutrition Corporation, Minneapolis, MN). The composition of Vivonex is 82% carbohydrate, 15% protein, 3% fat. Daily caloric requirements were calculated using the Galveston Adolescent formula $1500 \text{ kcal/m}^2 \text{ total body surface area} + 1500 \text{ kcal/m}^2 \text{ body surface area burned}$,⁹ and orders were written to deliver calories at rates related to meet these requirements. Enteral feedings were continued until the patient could consume adequate calories from hospital trays necessary as calculated from the formula above. Patients were allowed to convert from tube-feeding to oral nutrition as tolerated.

Patients were on bedrest for 4 days after grafting and excision, and ambulated daily thereafter until the next excision and grafting procedure (7 to 14 days). Most patients underwent indirect calorimetry to determine resting energy expenditure (REE) within the first week of admission.

Study Design

To be included in this study, patients must have received at least one week of enteral tube feeding, no total parental nutrition, and had no major amputations during their acute hospitalization. Nutritional intake and weights were analyzed for the first 30 days after admission. The dry weight was documented as the lowest weight between admission and seven days after the first surgery. Weights were taken while the patient was nude. Patient weights and demographic information were collected from the electronic medical record.

The volume of tube-feeding delivered per hour was determined for each patient by reviewing the documentation in the electronic medical record. The concentration of tube-feeding was matched to the order that was written for the corresponding time. The volume delivered per day was calculated by summing those delivered between 7:00 AM and 6:59 AM the next day. The daily sums were determined this way as it was when the nurses, who recorded the volume of tube-feeding delivered, change shifts.

The daily volume of tube-feeding was multiplied by the concentration that was delivered throughout most of the 24 hour period. Vivonex TEN delivers one calorie per one milliliter, thus the resultant number (volume in ml x concentration) is equivalent to the number of calories delivered in one day. The number of calories delivered via tube-feeding from admission until day 30 was calculated for each patient each day. As the patient's wounds were healing, less tube-feeding was delivered in order to encourage

eating a regular diet. At this point, only days when the patient received $\geq 90\%$ of their calories via tube-feeding were included.

For the study, estimated calories recommended per day were calculated using the Curreri formula, the Galveston Adolescent formula, $REE \times 1.2$, and $REE \times 1.4$ (Table 1).^{9,18-20} Each recommendation was compared to calories delivered.

Indirect Calorimetry

Indirect calorimetry was performed at a resting state in a standardized environmental setting of 30°C, the normal temperature of our patient rooms in the burn unit. REE was measured with a Sensor-Medics 2900 metabolic cart (Sensor-Medics, Yorba Linda, CA). Inspired and expired gases were collected and the composition was analyzed at sixty-second intervals. Carbon dioxide production, volume of and oxygen consumption values were reviewed and accepted when they were at a steady state for at least five minutes. From these measurements, the average REE was then calculated.

Data Analysis

Patient demographics were summarized as means with standard deviations for continuous variables, or as counts with corresponding percentages for categorical variables. Patient weight over time was modeled by a mixed linear model, adjusting for the covariates dry weight, TBSA, age, gender, and presence of inhalation injury, while blocking on subject to account for repeated measures. Percentage of dry weight and calories delivered over time were each modeled similarly.

Differences between calories delivered by tube-feeding and the recommendations by each formula were separately modeled as a function of days post-admission by a generalized additive mixed model, blocking on subject, and accounting for the non-linear relation between calorie difference and day.²¹ The same differences were also modeled simultaneously as a function of days post-admission and feeding formula with an interaction between days and formula, blocking on subject. Statistical analyses were performed using R statistical software (R Core Team, 2013, version 3.0.1).²² A 95% level of confidence was assumed.

RESULTS

Patients Studied

Table 2 summarized patient demographics. This study included 45 patients who were about 44 years of age and predominantly male. They had an average TBSA burned of 41% with 22% 3rd degree burned. The patients had an average length of stay of 37 days and stayed approximately one day per percent burn (Table 2).

Effects on Weight

Mean weights declined by approximately 11 kg, as summarized in Figure 1. The model shows that each kilogram increase in dry weight was associated with a mean retention of 0.9 kilogram ($p < 0.0001$). Each additional day was associated with a 0.4 kilogram decrease in weight ($p < 0.0001$).

During the initial 30 days following admission, mean weights declined by approximately 14%, as summarized in Figure 2. The model shows that each kilogram increase in dry weight was associated with a mean retention of 1.6 percent higher weight ($p < 0.0001$). Each additional day was associated with a 0.5 percent decrease in weight ($p < 0.0001$).

Calories Delivered

Calories delivered over time are summarized in Figure 3. There was a significant relation with dry weight ($p = 0.045$), total body surface area burned ($p = 0.013$), age ($p = 0.027$), and presence of inhalation injury ($p = 0.0015$) to calories delivered. Each 1 kg increase in dry weight was associated with 15 additional calories delivered. Each 1% increase in TBSA was associated with 16 additional calories delivered. Each 1 year increase in age was associated with 17 additional calories delivered. The presence of an inhalation injury was associated with 611 additional calories delivered.

Differences between actual calories delivered and the recommendations by $REE \times 1.2$, $REE \times 1.4$, the Curreri formula, and the Galveston formula are summarized in Figure 4 as functions of days post-admission. The mean deficit per patient was 1200, 1700, 2500, and 3000 calories per day, respectively. The caloric deficits were greatest in the first few days following admission.

DISCUSSION

There are a variety of formulas that have been created to maintain body weight in patients after a severe burn.²³ This array of formulas implies that no one formula is particularly better than another when it comes to feeding burned patients. Although, there is not a set amount of calories that should be delivered to burned patients, there is one goal which should be met: catabolism should be decreased, such that the patient does not lose weight.¹⁷

It has been shown that with aggressive and early enteral feeding catabolism is attenuated.^{7,8} In order to estimate the amount of calories recommended to adults with massive burns, one can use the Curreri formula, which is stratified based on age.¹⁸ At our institution, we use the Galveston Adolescent formula,⁹ which

recommends more calories than the Curreri formula,¹⁸ and is more user-friendly. Additionally, REE can be used in combination with the Galveston formula in order to find a balance between the formula estimation and the calculated estimation. At our institution, calories are ordered at 1.2 to 1.4 x REE. Recommendations in the literature vary from 0.8 to 2.0 x REE.^{11-13,24}

It should be noted that formulas are estimations of caloric needs, which can be affected by a variety of clinical events. Overall, this rate of tube-feeding is well accepted, but at times patients are unable to tolerate it leading to the delivery of fewer calories. In this study, patients with massive burns lost approximately 14% of their dry weight within 30 days of admission. This correlates with a deficit of approximately 1200-2500 calories delivered per day. It was found that with each 1 kg increase in dry weight only 15 additional calories were delivered, when according to the Curreri formula 25 kilocalories should have been delivered for every kilogram increase. Similarly, with each 1% increase in TBSA burned only 16 additional calories were delivered, when 40 kilocalories per percent should have been delivered according to Curreri.¹⁸

The current illustration of the inadequacy of caloric delivery seems remarkable. The insufficiencies may be explained by, the practice of stopping tube feeding for surgery, wound care, research studies, clinical testing, and other interruptions. This practice may explain the deficit of calories delivered, and may be inevitable. Although, when tube-feeding is turned off, the amount of calories missed during that time should be made up throughout the rest of the day.

In order to address this issue, adjustments to current formulas, practices, or tabulations, may be needed to account for times without tube-feeding. Education and vigilance are important in order to assure nutrition orders are followed and that each patient receives the nutrition and calories they require. In burn units, food has often been called medicine to a burn patient, such that, it is necessary and serves a purpose for their recovery. For example, it attenuates the hypermetabolic state, improves wound healing, decreases catabolism, and increases the chance of survival.^{7,8,25,26} Since nutrition plays such a substantial role to burn patients, it is imperative that adequate formulas be utilized and daily monitoring of total intake, not just rate delivered hourly, be performed.¹⁷

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REFERENCES

1. Yarborough M, Herndon D, Curreri P. Nutritional management of the severely injured patient. *Contemporary Surgery*. 1978;13:15-20.
2. Lee JO, Herndon DN. Modulation of the post-burn hypermetabolic state. *Nestle Nutrition workshop series. Clinical & performance programme*. 2003;8:39-49; discussion 49-56.
3. Herndon D. Mediators of metabolism. *The Journal of trauma*. 1981;21(701-705).
4. Jeschke MG, Chinkes DL, Finnerty CC, et al. Pathophysiologic response to severe burn injury. *Annals of surgery*. Sep 2008;248(3):387-401.
5. Hart DW, Wolf SE, Mlcak R, et al. Persistence of muscle catabolism after severe burn. *Surgery*. Aug 2000;128(2):312-319.
6. Chang DW, DeSanti L, Demling RH. Anticatabolic and anabolic strategies in critical illness: a review of current treatment modalities. *Shock*. Sep 1998;10(3):155-160.
7. Dominioni L, Trocki O, Fang CH, et al. Enteral feeding in burn hypermetabolism: nutritional and metabolic effects of different levels of calorie and protein intake. *JPEN. Journal of parenteral and enteral nutrition*. May-Jun 1985;9(3):269-279.
8. Mochizuki H, Trocki O, Dominioni L, Brackett KA, Joffe SN, Alexander JW. Mechanism of prevention of postburn hypermetabolism and catabolism by early enteral feeding. *Annals of surgery*. Sep 1984;200(3):297-310.
9. Hildreth MA, Herndon DN, Desai MH, Duke MA. Caloric needs of adolescent patients with burns. *The Journal of burn care & rehabilitation*. Nov-Dec 1989;10(6):523-526.
10. Hildreth MA, Herndon DN, Parks DH, Desai MH, Rutan T. Evaluation of a caloric requirement formula in burned children treated with early excision. *The Journal of trauma*. Feb 1987;27(2):188-189.
11. Goran MI, Peters EJ, Herndon DN, Wolfe RR. Total energy expenditure in burned children using the doubly labeled water technique. *The American journal of physiology*. Oct 1990;259(4 Pt 1):E576-585.

12. Gore DC, Rutan RL, Hildreth M, Desai MH, Herndon DN. Comparison of resting energy expenditures and caloric intake in children with severe burns. *The Journal of burn care & rehabilitation*. Sep-Oct 1990;11(5):400-404.
13. Hart DW, Wolf SE, Herndon DN, et al. Energy expenditure and caloric balance after burn: increased feeding leads to fat rather than lean mass accretion. *Annals of surgery*. Jan 2002;235(1):152-161.
14. Askanazi J, Rosenbaum SH, Hyman AI, Silverberg PA, Milic-Emili J, Kinney JM. Respiratory changes induced by the large glucose loads of total parenteral nutrition. *JAMA : the journal of the American Medical Association*. Apr 11 1980;243(14):1444-1447.
15. Klein CJ, Stanek GS, Wiles CE, 3rd. Overfeeding macronutrients to critically ill adults: metabolic complications. *Journal of the American Dietetic Association*. Jul 1998;98(7):795-806.
16. Saffle JR, Graves C, Cochran A. Nutritional support of the burned patient. In: Herndon D, ed. *Total Burn Care*. London: Saunders Elsevier; 2012.
17. Newsome TW, Mason AD, Jr., Pruitt BA, Jr. Weight loss following thermal injury. *Annals of surgery*. Aug 1973;178(2):215-217.
18. Curreri PW, Richmond D, Marvin J, Baxter CR. Dietary requirements of patients with major burns. *Journal of the American Dietetic Association*. Oct 1974;65(4):415-417.
19. Saffle JR, Medina E, Raymond J, Westenskow D, Kravitz M, Warden GD. Use of indirect calorimetry in the nutritional management of burned patients. *The Journal of trauma*. Jan 1985;25(1):32-39.
20. Turner WW, Jr., Ireton CS, Hunt JL, Baxter CR. Predicting energy expenditures in burned patients. *The Journal of trauma*. Jan 1985;25(1):11-16.
21. Wood S. *Generalized additive models: an introduction with R*. CRC Press; 2006.
22. *R: a language and environment for statistical computing*. [computer program]. Version 3.0.1. Vienna, Austria: R Foundation for Statistical Computing; 2013.
23. Lee JO, Benjamin D, Herndon DN. Nutrition support strategies for severely burned patients. *Nutrition in clinical practice : official publication of the American Society for Parenteral and Enteral Nutrition*. Jun 2005;20(3):325-330.
24. Williams FN, Herndon DN, Jeschke MG. The hypermetabolic response to burn injury and interventions to modify this response. *Clinics in plastic surgery*. Oct 2009;36(4):583-596.
25. Hart DW, Wolf SE, Chinkes DL, et al. Effects of early excision and aggressive enteral feeding on hypermetabolism, catabolism, and sepsis after severe burn. *The Journal of trauma*. Apr 2003;54(4):755-761; discussion 761-754.
26. Mosier MJ, Pham TN, Klein MB, et al. Early enteral nutrition in burns: compliance with guidelines and associated outcomes in a multicenter study. *Journal of burn care & research : official publication of the American Burn Association*. Jan-Feb 2011;32(1):104-109.

Table 1. Formulas and calculations used to estimate calories required to maintain body weight in a burned patient.

Table 2. Demographics of patients included in this study.

Figure 1. Adjusted mean weight over time. Shaded regions indicate 95% confidence intervals.

Figure 2. Adjusted mean percentage of dry weight over time. Shaded regions indicate 95% confidence intervals.

Figure 3. Adjusted mean tube-fed calories given over time. Shaded regions indicate 95% confidence intervals.

Figure 4. Differences between calories delivered by tube feeding and calories recommended per formula. The shaded regions span the standard error. REE = resting energy expenditure.

Table 1. Formulas and calculations used to estimate calories required to maintain body weight in a burned patient.

	Age Range (years)	Formula / Calculation
Galveston	12 - 16	$1500 \text{ kcal} / \text{m}^2 \text{ TBSA} + 1500 \text{ kcal} / \text{m}^2 \text{ TBSA burned}$
Curreri	16 - 59	$25 \text{ kcal} / \text{kg of weight} + 40 \text{ kcal} / (\% \text{ TBSA})$
Curreri	≥ 60	$20 \text{ kcal} / \text{kg of weight} + 65 \text{ kcal} / (\% \text{ TBSA})$
REE	Any	Typically $1.2 - 1.6 \times \text{REE}$

TBSA = total body surface area

REE = resting energy expenditure

Table 2. Demographics of patients included in this study.

Variable	Value
n	45
Age, years	44 \pm 16
Gender, males (%)	35 (78%)
LOS, days	37 \pm 25
TBSA burn, %	41 \pm 17
3 rd burn, %	22 \pm 21
Day / % burn, day	1.0 \pm 0.4

LOS = length of stay

TBSA = total body surface area

Data presented as means \pm SD, or counts (%).

Weight Loss over Time

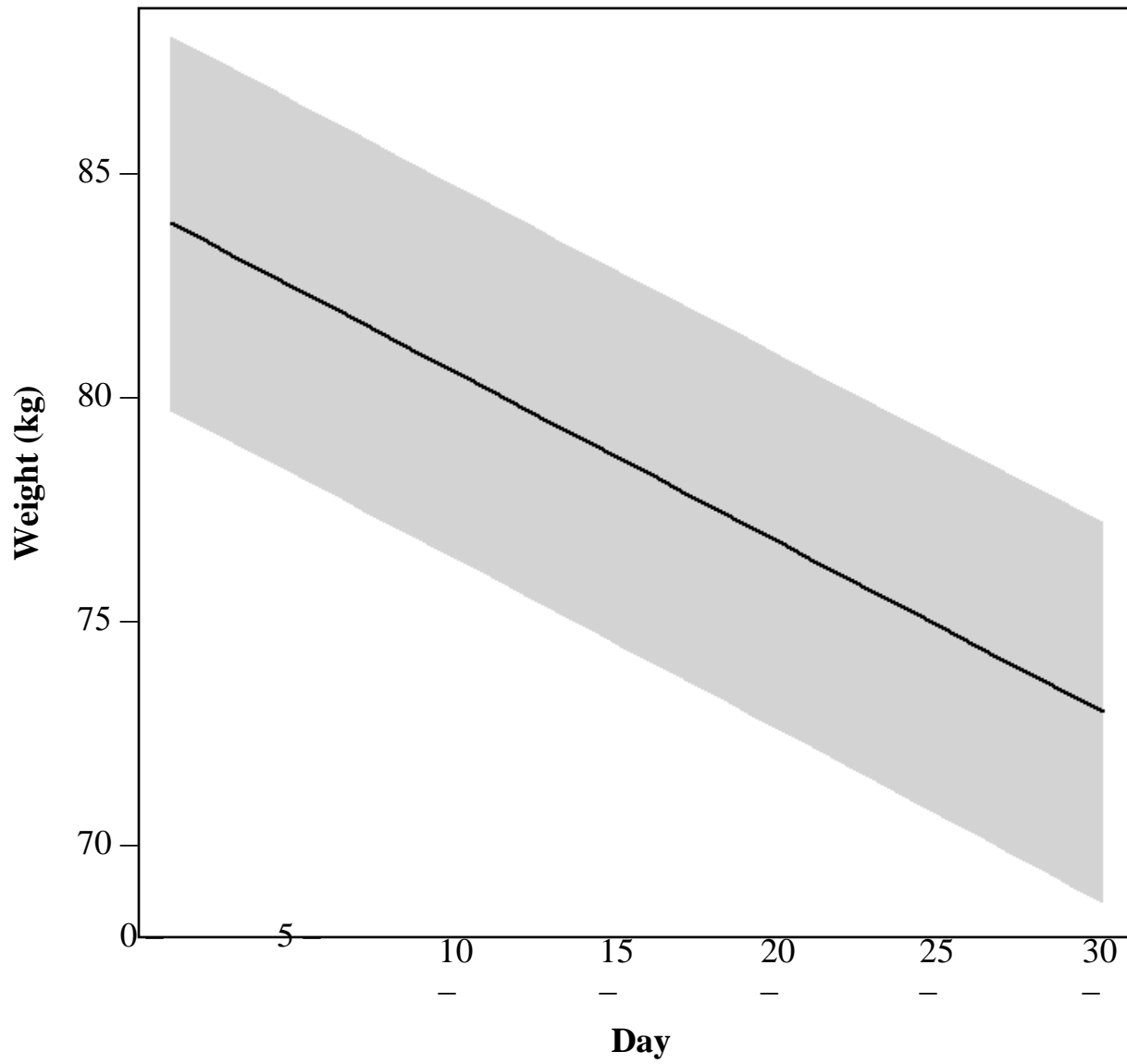


Figure 1. Adjusted mean weight over time. Shaded regions indicate 95% confidence intervals.

Percent Weight Loss over Time

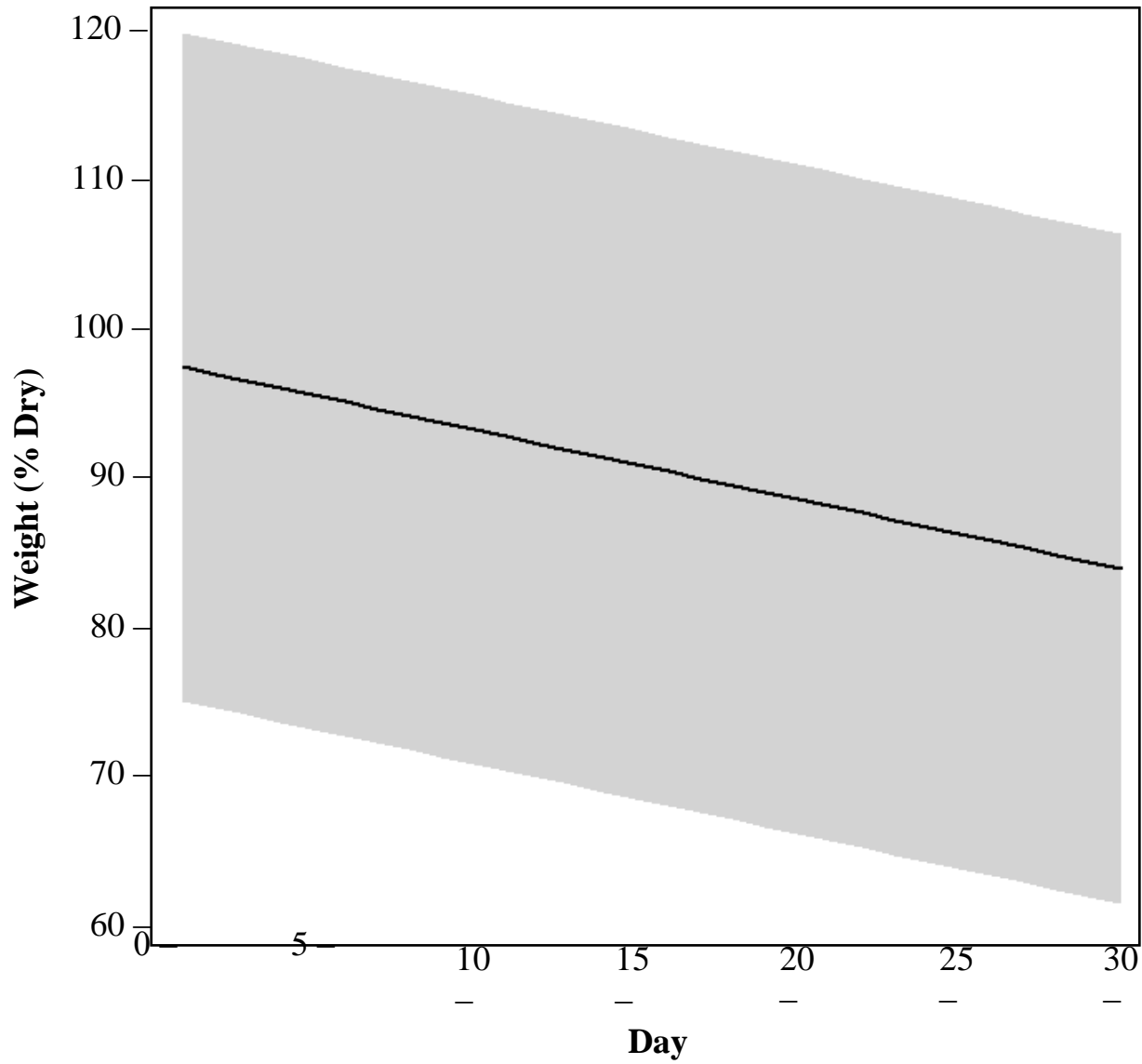


Figure 2. Adjusted mean percentage of dry weight over time. Shaded regions indicate 95% confidence intervals.

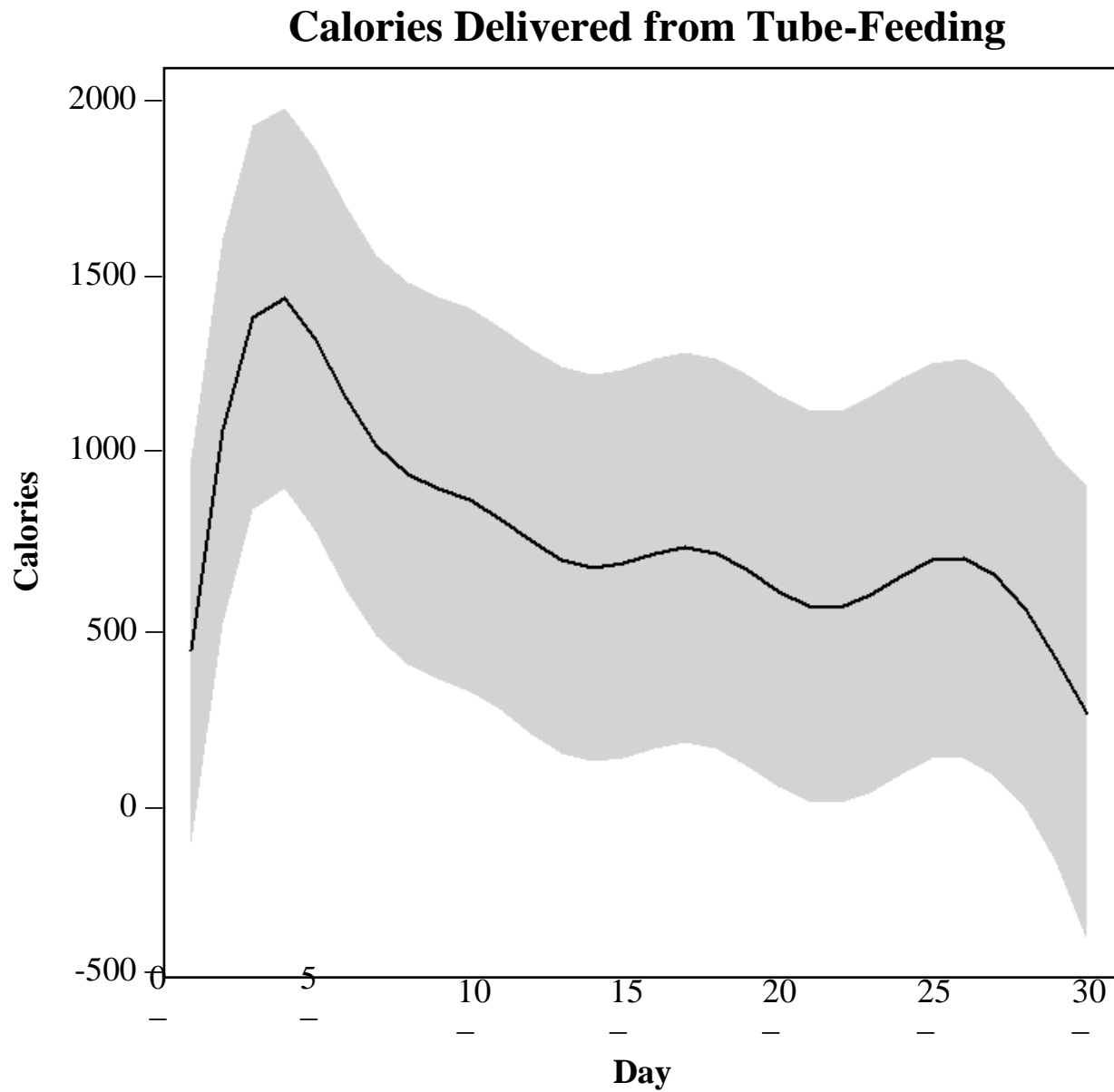


Figure 3. Adjusted mean tube-fed calories given over time. Shaded regions indicate 95% confidence intervals.

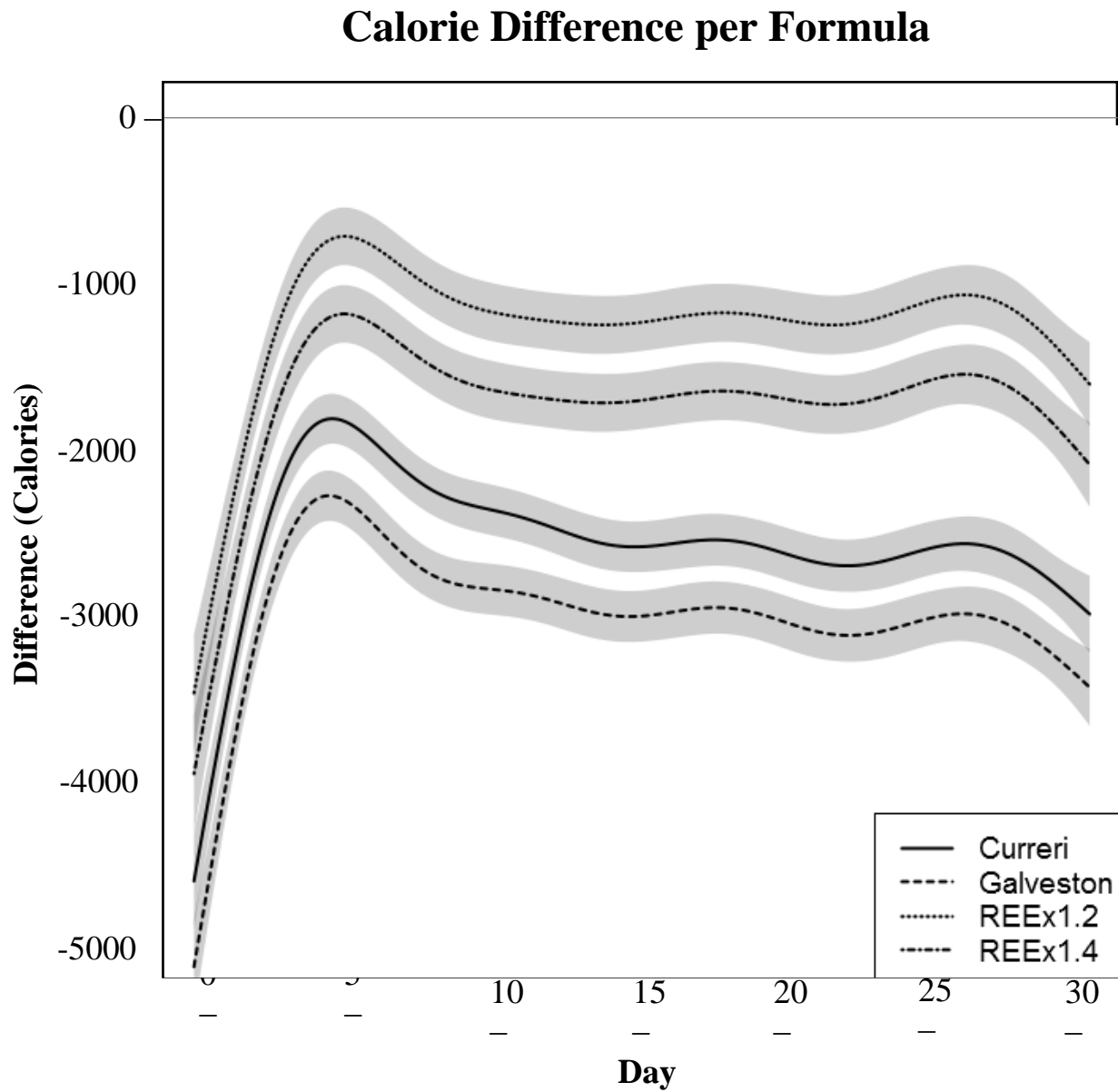


Figure 4. Differences between calories delivered by tube feeding and calories recommended per formula. The shaded regions span the standard error. REE = resting energy expenditure.

Appendix 2

Description of the Nutrition Decision Support System

The Nutrition Decision Support System software offers the user a nutrition recommendation based on individual patient data entered into the system by the bedside provider. Upon starting the application, the user is prompted to provide patient information as well as the enteral formula that will be used to feed the patient (Figure 1). Based on this information the system computes a caloric goal per day for that patient as well as the hourly rate required to reach that goal.

Initiate session

Session Information

Directions:

1. Enter patient description below. Click on estimate if data is unknown.
2. Select an enteral formula option below.
3. Kcal goal and hourly goal rate will automatically calculate. Change the max rate if desired.
4. When patient is hemodynamically stable (no pressors and lactate WNL) and feeding tube placement is confirmed by X-ray, hit the **Start** button.

Patient Information:

Patient Name: Gender:

Date of Burn: ☐ Estimate Age: ☐ Estimate

Date of admit: ☐ Estimate Height: cm in ☐ Estimate

%TBSA burn: ☐ Estimate Weight: kg lbs ☐ Estimate

Comments:

Nutrition Information:

Enteral Formula: ☐ Mixture: (1 can Promote, 6 packs Propass, 18 Tablespoons Polycose, 240 mL Water)

☒ Osmolite 1.2

☐ Novasource Renal

☐ Other

Kcal goal per day:

Hourly goal rate: mL/hr

Max rate: mL/hr (default is 180)

Refresh Calculation **Start**

Figure 1: Session setup screen

Once the nutrition session starts, the Nutrition DSS will prompt the user each hour to enter how much enteral nutrition the patient received during the previous hour (Figure 2).

Figure 2: Hourly nutrition rate prompt

Based on this information, the system then provides the user with a new recommended enteral nutrition rate for the next hour along with the reason for that recommendation (Figure 3). This process repeats itself every hour for the duration of the session, with the system utilizing a mathematical model (*at this point not specific to the physiologic condition of the patient, as the only input is how much was received*) to attempt to provide the caloric goal.

Figure 3: Hourly nutrition rate prompt with new recommendation

If at some point, however, the user indicates that the recommendation provided by the system was not followed, the system will prompt the user for a reason and, based on that answer, it will ask questions to assess the perceived status of the patient based upon the judgment of the provider, and then provide new instructions and recommendations (Figure 4).

Please select the reason(s) the patient did not receive the recommended amount:

- Ileus
- Emesis
- Pressors
- High Residuals
- Distended Abdomen
- Surgery
- Scheduled Interruptions (Procedures, Diagnostic Tests, Extubation, Shower, etc)

Submit

Is Patient being fed post pylorically?

Yes No

Suction Stomach & record amount discarded: 20 mL

Submit

Recommended Rate: 0 mL/hr

Emesis - will hold TF for 0 hr(s) or until DHT placed & confirmed with KUB.

Continue

Other options:

To return to the previous question, please click the Return button: Return

If questions above are not consistent with patient situation, please click the Clarify button: Clarify

To return to the Patient Information panel to make changes to the patient description, enteral formula, kcal goal, hourly goal rate, or max rate, please click the Patient Info button: Patient Info

Figure 4: Example of the situation assessment prompt with new recommendation

In addition to prompting the user every hour for the enteral rate, every 4 hours the system will also ask the user to measure gastric residuals (Figure 5). If the residual volume is found to be higher than preconceived limits (*that have not been tested yet*), the system will then adjust the recommendation provided to account (Figure 6).

Please enter amount of enteral nutrition the patient received from 19:00 to 20:00: 88 mL Submit

Please check gastric residuals (with NGT, never with DHT) and enter amount: 0 mL ☐ Unable to check

Submit

Other options:

To return to the previous question, please click the Return button: Return

If questions above are not consistent with patient situation, please click the Clarify button: Clarify

To return to the Patient Information panel to make changes to the patient description, enteral formula, kcal goal, hourly goal rate, or max rate, please click the Patient Info button: Patient Info

Figure 5: Residuals check prompt

Please enter amount of enteral nutrition the patient received from 19:00 to 20:00: mL

Please check gastric residuals (with NGT, never with DHT) and enter amount: mL ☐ Unable to check

Return up to 300 mL of residuals and enter amount discarded here (and in I&O's in chart): mL

Recommended Rate: mL/hr

Will continue TF at previous rate and re-check residuals in 2 hrs or will run TF at 10 mL/hr and re-check residuals in 2 hrs.

Other options:

To return to the previous question, please click the Return button:

If questions above are not consistent with patient situation, please click the Clarify button:

To return to the Patient Information panel to make changes to the patient description, enteral formula, kcal goal, hourly goal rate, or max rate, please click the Patient Info button:

Figure 6: Example of instructions and new recommendation for high residuals

All the measurements and recommendations are presented in graphical form (Figure 7). Relevant data such as current enteral formula, caloric goal and recommended rate are also shown.

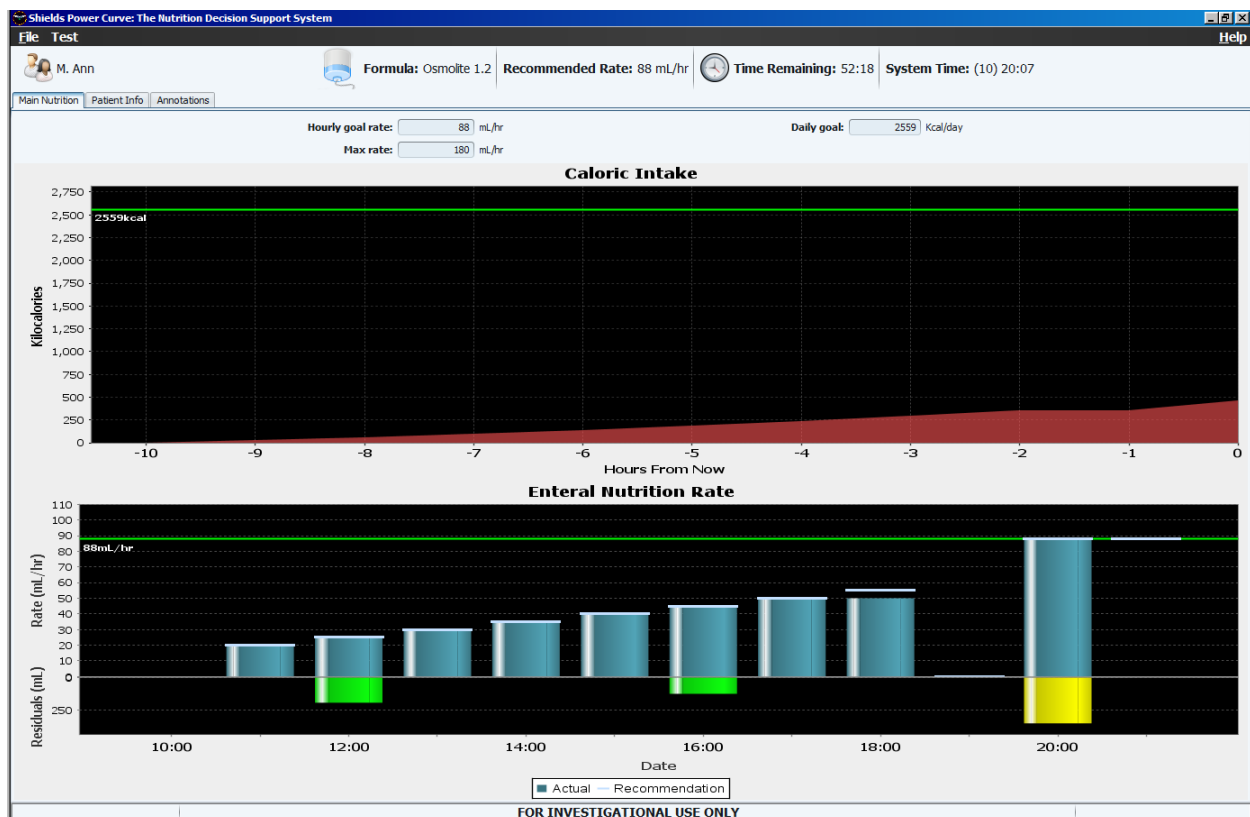


Figure 7: Main application window with graphical displays